Promoting Cover Crop Adoption to Improve Water Quality in Agricultural Landscapes

Thesis

Presented in Partial Fulfillment of the Requirements for the Honors Degree of Bachelor of Science in the School of Environment and Natural Resources

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Spring 2018

Abstract

Nutrient loading and associated algal blooms resulting from agricultural runoff are a pressing environmental concern for the Great Lakes. Cover crops are an important Best Management Practice (BMP) useful for reducing nutrient runoff while providing a wide variety of other on-farm benefits. 22 semi-structured interviews were conducted to learn more about the motivations, benefits, and constraints associated with cover crop adoption among different types of farmers. Three distinct groups of farmers were identified within the sample, sharing certain characteristics: 1) enthusiastic (or early) adopters, 2) new (or middle) adopters, and 3) tentative (or late) and non-adopters. Middle and tentative/non-adopters lacked awareness of the diverse potential benefits of cover crops relative to enthusiastic or early adopters. As a result, emphasizing these benefits may be critical to decreasing skepticism toward cover crops as an effective and economic management tool and promoting future adoption. Demonstration farms are a popular outreach tool used to provide such information about BMPs. Pre- and post-surveys were also conducted at the Blanchard Valley and Seneca County Demonstration Farms to determine the impact of the events on farmer knowledge, beliefs and concerns. Preliminary results indicate that the demonstration farms significantly improved the participants' confidence in their ability to implement cover crops but had no significant impact on farmer knowledge. These results provide evidence that current outreach and communication efforts are having a positive effect, but continued effectiveness will hinge on providing concrete examples of long-term economic benefits and diverse on-farm benefits, such as resiliency and livestock opportunities.

Acknowledgements

I would like to thank my advisor, Dr. Robyn S. Wilson, for the time, effort, and guidance she provided throughout the research process and writing of this thesis. I am grateful to Emily Walpole and Hugh Walpole for their assistance and support, as well as the SENR Honors Committee and the Ohio State University Honors & Scholars Enrichment Grant Committee for generously funding my thesis research.

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1.1 The Problem: Algal Blooms in the Western Lake Erie Basin

In the western basin of Lake Erie, elevated levels of phosphorus, nitrogen, and sediment loading are causing harmful algal blooms (HABs), which are a small subset of algal species that produce toxins and/or excessive blooms. Exposure to HAB toxins and compounds can have very serious human health, environmental, and economic consequences. Drinking or swimming in water containing HABs can cause rashes, stomach or liver illness, respiratory problems, and neurological effects in humans (Ohio EPA 2010). HABs can kill fish and other animals because of toxin uptake in small fish and shellfish that are eaten by larger animals like turtles and birds, causing these toxins to move up the food chain and seriously damage the freshwater ecosystem (Ohio EPA 2010). HABs can also create dead zones in the water, raise treatment costs for drinking water, and harm industries that are dependent on clean water (Ohio EPA 2010). The closing of the City of Toledo's water treatment plant for two days in 2014 was a critical event that brought even greater attention to the environmental and public health problems associated with HABs. $10.7 billion annually, or 30% of Ohio's tourism revenue, comes from Lake Erie visitation and HABs will affect more than 100,000 northern Ohio jobs if regional tourism declines (Great Lakes Commission 2014). Sources of excessive nitrogen and phosphorus include point sources, such as wastewater treatment plants, and non-point sources, such as agricultural nutrient application runoff (Ohio EPA 2010).

Agricultural row crops (i.e. corn and soybean fields) account for 59 percent of land use in the Ohio Lake Erie watershed, and approximately 72 percent of the land draining into the western Lake Erie basin is from row-crop agriculture (Ohio EPA 2010). Agriculture is vital to

meet the demands of a growing population, and to sustainably do so farmers must provide more food from less land through more efficient use of natural resources, and with as little environmental impact as possible (Hobbs 2007; Dunn et al. 2016). HAB impacts are expected to worsen in the future as a result of climate change (i.e., warmer surface water temperatures, intensified rain events) and the need for agricultural conservation measures in the U.S. will be critical (Michalak et al. 2013; Hatfield et al. 2014; Dunn et al. 2016).

1.2 Cover Crop Benefits

The Ohio Lake Erie Phosphorus Task Force discusses recommended agricultural best management practices (BMPs) for reducing nutrient loading to Lake Erie, with cover crops identified as one of several useful practices. In terms of promoting water quality, cover crops are planted to help retain fertilizer during the time in which the fields are more vulnerable to surface runoff, in between commodity crop harvest and planting. Strategically located and widely implemented use of cover crops can effectively reduce dissolved reactive phosphorus (DRP), especially in fields with particularly high nutrient runoff (Bosch et al. 2013). Cover crops retain phosphorus by retaining water, therefore less soluble phosphorus on the soil surface is available to enter nearby waterways. Unger and Vigil (1998) analyzed cover crop effects related to water use and found that the effect of cover crops was mostly positive and that they provide additional nutrient cycling benefits compared to other practices to conserve water, such as conservation tillage.

Although cover crops are primarily thought of as a tool to reduce erosion and improve soil health, they also reduce soil compaction, recycle nutrients, improve soil tilth and structure, fix nitrogen, and increase biological diversity (Ohio EPA 2010; Tillman et. al 2004). In addition,

there is growing evidence that cover crops increase resilience in the face of both drought conditions and increasingly intensive rainfall (SARE 2015). Cover crops alleviate drought stress by increasing infiltration rates and soil moisture content, enhance soil quality through reducing compaction and increasing organic matter, and lessen erosion as a result of improved soil structure (Dunn et al. 2016).

Cover crops may be also be used to effectively control weeds because they provide a living surface cover that obstructs areas where weeds would normally be able to grow, thus limiting the need for herbicides or mechanical tillage (Marcillo & Miguez 2017). In the 2017 Cover Crop Survey Analysis conducted by Sustainable Agriculture Research & Education (SARE), a major cover crop benefit reported was better control of herbicide-resistant weeds. 69 percent of respondents said cover crops always or sometimes improved control of herbicide resistant weeds, which is significant as a majority of respondents (59 percent) reported having herbicide-resistant weeds in some of their fields (SARE 2017).

The agronomic and environmental benefits of cover crops lead to economic benefits for farmers that increase over time. Cover crops are plants that are mainly used to benefit soil rather than crop yield. However, cover crops have been shown to increase crop yields (SARE 2017). SARE's 2017 Cover Crop survey participants reported that after planting cover crops corn yields increased an average of 2.3 bushels per acre, or 1.3 percent; soybean yields increased 2.1 bushels per acres, or 3.8 percent; and wheat yields increased 1.9 bushels per acres, or 2.8 percent. The yield benefit can appear in as little as one year after cover crop adoption, and farmers will begin seeing other benefits, such as improved soil health, several years after adoption (SARE 2017). SARE's Cover Crop Survey Analysis shows that yield increases lead to increased economic return for farmers while also providing many other benefits in the long-term. Cover crops can

improve the quality of cash crops over time by contributing additional nitrogen to the cash crop, while also reducing fertilizer application requirements, which reduces costs of chemicals, management costs, and time spent in the field (Marcillo & Miguez 2017). In addition, cover crops provide synergistic benefits with no-till or strip-till because cover crop roots help improve soil structure and alleviate compaction through the addition of organic matter and compacted soils penetration by cover crop roots (Kladivko et al. 2014). Cover crops are most beneficial and cost-effective using no-till management practices, which reduce on-farm energy use, and can cut out residual herbicides from farming operations while reducing the costs of chemicals, such as pesticides, by as much as 50 percent (Gruver 2008; Clark 2007).

1.3 Cover Crop Constraints and Barriers

Adoption of many recommended BMPs is low in agriculture, and when such practices are used, farmers do not always fully implement the recommendation (e.g. producers may over apply fertilizer due to reliance on dealer information rather than technical advice from extension or NRCS) (Osmond et al. 2014). For cover crops specifically, one estimate suggests that only 18 percent of farmers in the Corn Belt region have adopted cover crops despite the numerous benefits previously mentioned (Singer et al. 2007). A 2013 study focused on farmers in the Maumee watershed of Ohio found that 7.9% plant cover crops all the time, while 42.3% used cover crops sometimes. These adoption rates are drastically different from other BMPs like adjusting nutrient application rates based on soil testing, which 45.6% of farmers practiced all of the time (Wilson et. al 2013). According to the USDA's Census of Agriculture, cover crops were planted in less than 5% of the nation's total row crop land in 2012 (USDA 2012). However, SARE's 2017 Cover Crop Survey Analysis showed that acreage planted in cover crops nearly

doubled from 2012 to 2017. Since SARE and CTIC began surveying cover crop usage among farmers in 2012, cover crop acreage among participants has steadily increased (SARE 2017). In 2017, farmers expected to increase their cover crop planting to an average of 451 acres per farm, up from the average of 400 acres reported in 2016 (SARE 2017). Both of these planting reports are significantly higher than the 216 acres of cover crops per farm reported in 2012 (SARE 2017). There are many reports that discuss low adoption rates across the nation and in Ohio; however, it seems farmers who are implementing cover crops on their farms are expanding their acres in cover crops due to the wide variety of benefits achieved.

The low adoption rate of cover crops is in part due to the up-front economic costs and the uncertainty created by the complex management process that makes achieving the benefits of cover crops potentially more challenging (CTIC et al. 2016). Cover crops add complexity to farming practices, require additional time and energy inputs, have the potential to introduce unwanted plants and pests into a field, and may have to be killed prior to planting the cash crop (Ward et. al. 2018). Although farmers recognize the value of cover crops in regards to soil and environmental protection, research shows that knowledge gaps about costs and management still persist as well as concerns about subsequent yields, which limits widespread cover crop adoption (Singer et. al. 2007). Yield uncertainty exists due to varying cover crop responses across regions, soils, climates, and management practices, which causes cash crop responses to subsequently vary (Marcillo & Miguez 2017). Many of the benefits are not experienced immediately, making the necessary investment of time and money less appealing in the short-term (Gruver 2008).

Successful seeding and establishment of cover crops in the fall can also be a major challenge for farmers in the Upper Midwest (Kladivko et. al. 2014). Cover crops generally need to emerge and grow to a minimum size to survive the winter and achieve their best growth in the

spring (Kladivko et. al. 2014). If cash crop harvest occurs early enough then cover crops can be seeded without major obstacles. However, for particular locations, the timing of harvest and post-harvest cover crop planting is very dependent on the weather and cash crop management in a particular year. In some years, corn and soybean crops are harvested relatively late, which does not leave time for fall cover crop growth before winter (Kladivko et. al. 2014). In addition, in colder climates like Minnesota and northern Iowa, soil surface freezing can occur much earlier, which limits establishment, fall growth, and winter survival of even the most reliable cover crops such as winter rye (Kladivko et. al. 2014). The tillage system is another important factor for cover crop success, and all types of tillage reduce the time available for cover crop growth (Kladivko et. al. 2014). Cover crops are generally easier to incorporate into no-till and strip-till systems compared to full-width tilled systems. This is due to earlier planting in reduced tillage systems in the fall, as well as increased cover crop growth time in the spring before termination (Kladivko et. al. 2014).

Cover crops can cause strain on farmers due to the extra management time needed to implement cover crops after harvesting a cash crop (Gruver 2008). Considerable flexibility and a willingness to take risks may be necessary for adoption given the variety of factors (i.e. weather, soil quality, tillage practices, etc.) that impact the potential risks and benefits associated with adoption (CTIC 2015; Burnett et al. 2018). According to Ward et al. (2018), information that may be useful to assist farmers in implementing cover crops given the potential barriers is 1) where/when cover crops should be implemented (timing), 2) how to best bundle different BMPs together, and 3) the transferability of research knowledge to commercial farms. Table 1.1 shows the overall benefits and barriers to cover crop adoption according to Ohio State University Extension.

Table 1. Advantages and disadvantages of using cover crops[1]

Advantages	**Disadvantages**
Reduce soil erosion, increase residue cover	Planted when time and labor is limited
Increased water infiltration	Additional costs (planting and terminating)
Reduce soil compaction/improve soil physical properties	Reduced or increased soil moisture depending on weather and/or management
Recycle nutrients, fix nitrogen with legumes	Difficult to incorporate cover crops with tillage
Improve weed control, beneficial insects, disease suppression	May increase insect pests
Wildlife habitat and landscape aesthetics	Allelopathic effects (e.g. cover crops inhibit cash crop growth)

1.4 Cover Crop Adoption Influences: Beliefs, Efficacy, and Knowledge

The factors most commonly studied as influential in adopting conservation-based BMPs include farmer characteristics (i.e. age, education, and income), cognitions and personality traits (i.e. environmental and risk attitudes), and farm characteristics (i.e. number of acres farmed, type of operation, etc.). Prokopy et al. (2008) summarized the conservation practice adoption literature and found that no attribute (e.g. acres, age, capital, education, experience, income, networks, land tenure awareness) consistently accounted for whether individuals had adopted nutrient management practices (i.e. variable rate application and application timing). However, prior research focuses largely on quantitative analyses of farm structure (e.g. size of farm, rental

[1] Adapted from Hoorman, J. 2009. Using Cover Crops to Improve Soil and Water Quality. The Ohio State University. Retrieved from https://blancharddemofarms.org/research/using-cover-crops-to-improve-soil-and-water-quality

aces, crops produced, farmer demographic information), rather than employing in-depth interviews to explore farmer decision-making that could better examine the wider range of factors that potentially contribute to the cover crop adoption decision-making process. McGuire et al. (2013) state that the dominant influence on BMP adoption is a number of psychological factors (i.e. beliefs, attitudes, values) rather than socio-demographic factors. Perceived efficacy is one such important psychological factor identified as relevant to the adoption of a risky and uncertain practice such as cover crops (Zhang, Wilson, Irwin, Martin, 2016). In a recent study, perceived efficacy, which is the belief that one can perform a novel or difficult task after seeing it work in different contexts, was positively correlated with a higher likelihood of adopting each of the nutrient application timing recommendations across a variety of farmers (Zhang et al. 2016). This indicates that policy and outreach efforts aimed at increasing farmers' perceived efficacy of practices could lead to higher cover crop adoption levels. Burnett et al. (2018) find similar results, where strengthening one's belief of cover crop effectiveness at reducing phosphorus loss doubled the odds of a farmer being *willing to adopt* cover crops and resulted in a seven-fold increase in the odds of a farmer having *already adopted* cover crops. Specifically, Burnett et al. (2018) found that the cover crop "innovators" (20%) had the greatest perceived efficacy and knowledge about 4R practices, the greatest concern about nutrients, and least amount of concern for barriers. The "future adopters" (38%) had fairly high efficacy, knowledge, and concern about nutrient issues as well, although they exhibited much higher concern about barriers than innovators, including concerns about fall planting windows, costs, and interference with commodity crop planting. Lastly, "laggards" (42%) were the most concerned with barriers, and had the lowest perceived efficacy of cover crops. This result suggests that farmers are more likely to adopt cover crops if they are able to observe and understand the benefits of the practice,

and that belief in the effectiveness of cover crops is an important factor that precedes participation; not only something that arises from seeing results in practice (Burnett et al. 2018). Author recommendations include emphasizing the overall effectiveness and long-term benefits associated with adopting cover crops to help overcome short-term costs as well as feelings of uncertainty and risk. Suggested methods of demonstrating this effectiveness include encouraging farmers to try out cover crops and lowering the barriers to doing so, attending local workshops or demonstration events, and providing biomass or other improvement calculations to get quantifiable benefit estimates (Burnett et al. 2018).

In addition to the importance of perceived efficacy, Burnett et al. (2018) found that using no-till, total acreage, and education levels, as well as perceived barriers to adoption, were all significant factors influencing willingness to use cover crops. Individuals utilizing no-till practices and individuals with higher levels of education were more likely to be using cover crops whereas individuals with more acres, or a less manageable amount of total acres, as well as individuals who had an increased focus on cover crop barriers they perceived as too difficult to overcome were less likely to be using cover crops (Burnett et al. 2018). Out of these factors, perceived efficacy of cover crops was by far the most influential factor and was much lower in "laggards", or skeptics/non-users of cover crops, compared to adopters (Burnett et al. 2018).

If perceived efficacy is the key factor explaining cover crop adoption, then this belief that a farmer can and will achieve benefits should be increased whenever possible. However, it may be difficult to increase perceived efficacy of cover crops compared to other conservation practices. Agronomic studies for cover crop effectiveness are more mixed and context-dependent, in part due to considerable uncertainty and complexity (e.g. there are many species to choose from, with variables of when and where to use them to achieve on-farm goals, with

uncertainties regarding the payback) (Wilson et al. 2017). As a result, Burnett et al. (2018) assert that, along with improving technical knowledge and perceived efficacy, providing ways to decrease costs and offset risks of adoption may be beneficial. Such approaches may include: 1) site-specific recommendations to reduce uncertainty, 2) cost-sharing and other measures to reduce economic risks, 3) peer-to-peer and hands-on learning to demonstrate success, and 4) highlighting the long-term benefits and quantifying the economic returns of using cover crops. These results and recommendations are consistent with a study of Iowa farmers where cover crop adoption was enhanced by a better understanding of the benefits, and the means by which risks could be mitigated (Arbuckle and Roesch-McNally 2015). Fortunately, it appears that a majority of farmers are willing to adopt conservation practices if these concerns can be addressed, including 30-40% of non-adopters (Burnett et al. 2018), making nutrient reduction goals possible with the appropriate assistance.

1.5 Demonstration Farms/Field Days

Previous research suggests the need for peer-to-peer and hands-on learning to demonstrate cover crop success and increase perceived efficacy (SARE 2018). Research on the effectiveness of outreach education in promoting conservation practice adoption is limited but demonstrates mostly positive associations between outreach and practice adoption (Jennings et al. 2012). Popular types of outreach education are demonstration farm tours, also known as field days. Field days are education events held on a farm or ranch hosted by a producer or extension agents (SARE 2018). These events demonstrate specific management practices, such as cover crop use, and equipment and/or highlight research methods and results (SARE 2018). Producers prefer to learn new methods and practices through hands-on activities and on-farm

demonstrations, and a field day encourages farmer-to-farmer learning and can highlight conservation success (SARE 2018). The cover crops results on the producer's farm may inspire others to make similar changes and try new practices.

Lemke et al. (2010) used a multiyear survey to assess how varying intensity levels of outreach influenced farmers' perceptions and adoption of conservation practices. Lemke et al. (2010) hypothesized that outreach would increase awareness of conservation concerns among farmers and would result in measurable increases in conservation-oriented farming practices. Survey results suggested that more intensive outreach efforts, such as one-on-one land owner visits and localized workshops and demonstration farm tours, can increase adoption of conservation practices associated with cost-share programs. Lemke et al. (2010) suggests that using landowners as the dissemination agent rather than local conservation agency staff may be more beneficial. In general, trusted individuals who understand farmers should be the ones carrying out demonstration farm tours to ensure maximum attendance and effectiveness (Jennings et al. 2012). Results from a watershed study in Utah found that one-on-one contact was the most effective means of communication (Jennings et al. 2012), whether this was through an extension agent working directly with a small number of farmers or through farmer-to-farmer training and farmer-led programs.

One surprising finding of the 2013-14 SARE Cover Crop Survey Analysis is that 63 percent of cover crop users reported to have never received cost-share assistance or payments to grow cover crops. In fact, just 8 percent of participants reported only planting cover crops when receiving financial assistance. This shows that financial incentives may be important to some farmers, but that the benefits of cover crops become apparent quicker than expected and inspire many farmers to continue cover crop usage (SARE 2014). Additionally in the 2013-14 SARE

Survey Analysis, cover crop users reported learning most about cover crop management through trial and error. Local workshops were reported as the second-most popular source of insight, followed by online research and regional meetings (SARE 2014). Overall, there is great enthusiasm for the soil health benefits of cover crops among users in the 2017 SARE Cover Crop Survey Analysis, with extensive appreciation for long-term cover crop benefits. Non-user survey participants reported needing more information and training, which could lead to higher attendance in demonstration farms if proven to be effective for increasing efficacy and knowledge of benefits.

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Chapter 2: Cover Crop Adopter Engagement and Effects of Demonstration Farm Tours on Farmer Efficacy and Knowledge

1. Introduction

Elevated levels of phosphorus and sediment loading are causing harmful algal blooms (HABs) in the western Lake Erie basin, which threaten the ecology and economy of the Great Lakes ecosystem (Ohio EPA 2010). Sources of excessive nitrogen and phosphorus include point sources, such as wastewater treatment plants, and non-point sources, such as agricultural nutrient application runoff (Ohio EPA 2010). Best management practices (BMPs) are useful for reducing agricultural non-point source pollution; however, agriculture remains a major contributor to the waterway pollution because farmers often do not adopt BMPs at the necessary levels (Liu et al. 2018).

Cover crops are an effective means of reducing nutrient runoff while also providing a wide variety of benefits to farmers (Ohio EPA 2010; Tillman et. al 2004). Cover crops are primarily thought of as a tool to reduce erosion and improve soil health, but they also reduce compaction, recycle nutrients, improve soil tilth and structure, fix nitrogen, and increase biological diversity (Ohio EPA 2010; Tillman et. al 2004). In addition, there is evidence that suggests cover crops increase resilience in the face of drought conditions and increasingly intensive rainfall (SARE 2015). Cover crops alleviate drought stress by increasing infiltration rates and soil moisture content, enhance soil quality through reducing compaction and increasing organic matter, and lessen erosion as a result of improved soil structure (Dunn et al. 2016).

Despite the diverse agronomic and economic benefits to farmers, cover crops have very low adoption rates, with approximately 8% of farmers reporting their consistent use in the Maumee watershed (Wilson et al. 2013). Reasons why adoption rates may be low are that cover

crops add complexity to farming practices, require additional time and energy inputs, have the potential to introduce unwanted plants and pests into a field, may have to be killed prior to planting the cash crop, and introduce yield uncertainties (Ward et al. 2018).

With continued climate change leading to stronger and more frequent algal blooms, the adoption of cover crops as a management practice for conventional farmers will become even more critical (Ohio EPA 2010). A key challenge will be to identify how best to increase adoption of cover crops and other recommended practices that reduce nutrient loss. One way to do this might be through hands-on activities and on-farm demonstrations, which are useful tools to encourage peer-to-peer learning and can highlight cover crop success (SARE 2018). Such events can build farmer confidence and increase the motivation and intention to adopt cover crops.

An important psychological factor identified in behavioral literature to be particularly relevant to adopting a risky and uncertain practice is efficacy. Perceived self-efficacy is a construct that deals largely with an individual's belief that they possess the skills and abilities necessary to perform an action or behavior (Artikov et al. 2006). Response efficacy is the belief in the effectiveness of an action or behavior to achieve benefits. The risk and motivation literature suggests that individuals take action to protect themselves from a hazard when they have high threat and coping appraisals (Witte & Allen 2000). Specifically, a person will perform an action if they believe that adopting the recommended action will result in increased benefits and reduced risks that are personally relevant to them (Floyd et al. 2000; Witte & Allen 2000). In this case, the recommended action is adopting cover crops. According to the literature, farmers would then be motivated to adopt cover crops if they perceived high risks associated with not using the practice (i.e. critical nutrient loss) and if they perceived cover crop adoption as feasible and likely to provide benefits they care about (i.e. nutrient and water retention). Wilson et al.

(2014) verified this process for intentions to adopt BMPs, demonstrating that farmers with a higher sense of efficacy and higher risk perception had more positive attitudes toward adopting additional BMPs on the farm.

The overarching goal of this thesis is to contribute to a greater understanding through in-depth qualitative research of the perceived benefits, barriers, and motivations driving cover crop adoption. This chapter presents the results of research focused on two hypotheses. The first hypothesis is that greater knowledge of the diverse benefits of cover crops and greater perceived efficacy will increase the likelihood that an individual has adopted cover crops. The second hypothesis is that demonstration farms will, in turn, increase knowledge of cover crops and the perceived benefits to promote greater efficacy and ultimately greater adoption.

2. Study Methodology

A mixed methods approach was used to collect the data presented here. Specifically, we used a mental models methodology to gain a more in-depth understanding of diverse cover crop users by conducting semi-structured interviews with farmers across the upper Midwest. Pre- and post-evaluation surveys were used to determine the success of demonstration farm events at increasing perceived self-efficacy and knowledge of diverse cover crop benefits and decreasing concern toward cover crop barriers and constraints.

2.1. Mental Models Approach

Mental models are simplified representations of the world that we use to help us make decisions; much in the way that a computer model helps us to simplify a situation to make predictions, our mental models help us to synthesize information and make decisions based on the most relevant factors. Mental models exist for numerous specific topics, and are constantly evolving through our daily experiences and social interactions (Morgan et.al. 2002, Jones et.al.

2011). Assessing the mental models of individuals and comparing them to an expert model of a system or hazard allows differences between groups to be identified and serves to highlight any misunderstandings or misconceptions. The mental models approach allows researchers to have experts define the general framework that guides the next steps of the research process. For this research, we focus on the perceived benefits and sense of efficacy among three farmer user groups regarding cover crops, although the original model development was much more broad.

To provide a point of comparison for our farmer participants, the first step was to develop an expert model[1]. The expert model was developed between April and August 2016 to provide a foundation or framework to guide the questions we posed to our farmer sample. The expert model eliminates any preset assumptions from researchers and allows experts to explain their understandings of why farmers adopt cover crops. This understanding essentially serves as the theoretical framework for data collection with the target audience. We conducted interviews over the phone with 11 experts from agencies such as the Natural Resources Conservation Service (NRCS), University Extension, County Soil and Water Conservation Districts (SWCDs), etc., as well as several farmers who currently use cover crops. By analyzing the data provided by these interviews, we developed a network of the main concepts that influence cover crop adoption decisions such as perceived benefits, types of motivations, risks, and barriers.

Although many of these concepts are important to make decisions regarding cover crop adoption, this thesis focuses specifically on concepts related to perceived benefits and efficacy. After the expert model was completed, the main concepts (see Table 2) were used to develop an interview protocol for farmer interviews. A semi-structured interview format was used, which

[1] Other researchers on this project developed the expert model. For more details on the expert model, refer to: Wilson, R.S., Walpole, E., Carros, O.R., and Walpole, H. 2017. Meeting in the Middle: Engaging the Next Wave of Cover Crop Adopters. The Ohio State University, School of Environment and Natural Resources.

entailed a series of open-ended questions to capture farmer's thoughts about cover crop adoption's main benefits, risks, etc. By asking these questions in an open-ended way (e.g. "what do you think the benefits of using cover crops may be"), it was possible to capture each individual's perceptions more accurately, while minimizing the influence of the research team on participant responses.

Semi-structured interviews were conducted over the phone between September 2016 and April 2017, with a total of 22 farmers participating. For the purposes of this study, it was desirable to interview the "early" or "middle" cover crop users who can be persuaded to adopt cover crops or aid others with information they have learned from their new experiences with cover crops. As a result, "late" or non-cover crop users who have no inclination to use cover crops, no matter the assistance or communication, were not included in our sample. Participants were all farmers, sampled from Indiana, Michigan, Ohio and Wisconsin[1]. The sample was developed in a number of different ways. First, we contacted local Soil and Water Conservation Districts (selected randomly from counties in those states that were in or adjacent to a watershed that drained into the Great Lakes) and/or extension personnel in each state and asked them to provide contact information for farmers. A number of participants were also found through snowball sampling, where participants were asked to provide contact information for others they thought would be willing to participate. The response rate was 31.4%, which was determined by dividing the total number of completed interviews (22) by the total number of participants with whom contact was made (70) (Morton et al. 2012).

After the interviews were completed, GMR Transcription Services transcribed them and then three team members coded them based on the concepts identified in the expert model. First,

[1] Part 1 of this project was funded by the National Wildlife Federation through the Great Lakes Protection Fund. These stakeholders were interested in a broad sample of individuals from states within the Great Lakes region.

we separately coded subsets of interviews to "calibrate" our coding process and identify the most important and useful set of codes. Then, I coded the interviews based on the revised coding document, which was updated throughout the coding process to ensure useful concepts were incorporated as participants mentioned new concepts not in the original expert model. After coding was complete, a final secondary coder, Emily Walpole, randomly chose and coded 20% of the interviews to assess intercoder reliability. Inter-coder checks were conducted to ensure that coding was being done in a consistent manner and that all concepts were being represented. A reliability coefficient of .9 was achieved from this check (meeting the minimum standard of .8) (Krippendorff 2004; Lacy et al. 2015). Table 2 shows the main categories of the coding structure used with a few exemplars of codes in each category. In total there were 60 specific codes used in the coding structure. The presence or absence of each of these 60 concepts in interviews were noted in transcripts and recorded as 0 (absent in interview) or 1 (present in interview) in a spreadsheet.

After the coding was complete, we calculated how frequently each code was mentioned in the interviews. Once the frequency was calculated for each of the 60 codes, it was easier to delineate trends and establish different farmer user groups (see Figure 2). Additionally, the frequencies with which codes were mentioned was useful for understanding why certain groups did not adopt cover crops and the reasons for non-adoption. If certain codes were not mentioned, the participant may not have knowledge of the code or the code may not be as salient as others, which is an important finding that can be used to create meaningful communications recommendations.

Table 2. Codebook categories and examples of codes in each category (see Appendix A for full codebook)

Main Category	**Sub-Category (if applicable)**	**Exemplar Code**	**Description**
Motivations/Constraints[1]	Individual	Perceived Efficacy	A belief that cover crops work in different contexts and can work on one's farm; results from exposure to peer success stories and site specific evidence
	Social	Landlord Influence	A need to make a landlord happy can be a motivation or a constraint based on landlord desires
	Market	Cost-sharing	Participation in incentive-based programs to off-set costs of CCs
	Regulation	Threat of Future Regulation	Adoption as a means to avoid future water quality regulation, desire to act before regulation forces adoption; CC as a BMP
	Management Factors	Livestock	Having livestock increases the benefit of CC as forage, as a way to treat manure, or a way to financially support farmers while they experiment with cover crops
	Physical Characteristics	High slope	Sloped region get more erosion benefits
Determinants of Success	N/A	Right CC Species	It is necessary to choose the right CC species for your resource goal, (cereal rye is to the most basic option)
		Start Simple	Being cautious; starting CCs in a small plot and/or with one type to try it out. A concept that was raised in interviews but not by experts.

Uncertainties	N/A	Benefits	Lack of clarity about when benefits will occur and/or have a positive effect on yield bottom line
Benefits	Short-term	Erosion Control	Reduce soil erosion
	Long-term	Weed control	Control weeds
Risks/Costs	N/A	Increased costs	Increased farm costs (seed, equipment/labor, chemicals, fuel, or wear on equipment), More organic matter can require more N to stabilize C (short-term expense)
Fundamental Goals	N/A	Improve water quality	Improve water quality; help with algal blooms

[1] In the expert model, we identify that some of these codes are constraining and motivating but can also be both.

2.2. Demonstration Farm Surveys

Pre- and post surveys were conducted on two different demonstration farms in Ohio, the Blanchard Valley Demonstration Farm Tour and a Seneca County demonstration farm tour. Post-surveys were completed immediately after the tour ended. Demonstration farm tours are education events held on a farm or ranch hosted by a producer or extension agents (SARE 2018). These events demonstrate specific management practices, such as cover crop use, and equipment and/or highlight research methods and results (SARE 2018).

There were 48 surveys completed from the Blanchard Valley Demonstration Farm Tours, which occurred between the spring and fall of 2017. In this survey, the goal was to help the Blanchard Valley Demonstration Farm network determine if their educational objectives were being met. Their objectives included increasing knowledge and behavioral intentions around monitoring phosphorus levels in the soil, improving soil health through cover crops and no-till,

placing fertilizer beneath the surface of the soil to decrease nutrient loss, and modifying how and where water flows in and around fields. A set of survey questions was created to focus on these four objectives, specifically assessing potential changes in knowledge about these four practices, confidence in one's ability to implement them, and current behavior and future intentions. Although this evaluation survey was not created specifically for this thesis, three questions from the survey overlapped with our goals; these questions assessed to what extent perceived efficacy and knowledge of the soil health benefits of cover crops increased after attending the tour (see Table 3).

There were 27 farmer participants from the Seneca County farm tour; however, only 13 participants granted consent to use their surveys for research purposes. In this survey, the goal was to determine whether the Seneca County demonstration farm tour increased knowledge of cover crop benefits, farmer confidence in their ability to implement cover crops, and decreased cover crop concerns (Table 4). All of these questions were pertinent to the goals of this project and were used to assess the impact of the farm tours on farmer knowledge, confidence, and concern. The data from both sets of evaluation surveys were analyzed using paired samples t-tests to identify any significant changes in the dependent variables before and after attending the tours.

Table 3. The measurement items used to assess psychological constructs in the Blanchard Valley Demonstration Farm Tour survey

Psychological Construct	Label for Analysis (see Figure 3 in Results)	Measurement Items
Perceived self efficacy	*Confidence*	I am confident in my ability to use cover crops to improve soil health.[1]
	Nutrient Loss Reduction	I know what steps I need to take to reduce nutrient loss on my farm.[1]
Knowledge/issue attentiveness	*Soil Health*	*I feel informed about…* Improving soil health through the use of cover crops and no-till.[2]

[1] Measured on a scale from -2 = strongly disagree to 2 = strongly agree where 0 = neither disagree nor agree
[2] Measured on a scale from 1 = not at all informed to 5 = extremely well informed

Table 4. The measurement items used to assess psychological constructs in the Seneca County Demonstration Farm Tour survey

Psychological Construct	**Labels for Analysis (see Figure 4-6 in Results)**	**Measurement Items**
Perceived efficacy (self and response efficacy)[3]	*Risks*	The risks associated with cover crops are manageable.[1]
	Soil Health	I believe that cover crops can improve soil health on my farm.[1]
	Confidence	I am confident in my ability to use cover crops to improve soil health.[2]
	Steps to Use	I know what steps I need to take to use cover crops on my farm.[2]
Knowledge[4]		*I feel informed about…*
	Benefits	The benefits of cover crops on my farm.
	Soil Health	Improving soil health through the use of cover crops and no-till.[3]
	Cover Crop Use	Using cover crops effectively on my farm.

[1] Measurement items demonstrate response efficacy
[2] Measurement item demonstrates self-efficacy
[3] Measured on a scale from -2 = strongly disagree to 2 = strongly agree where 0 = neither disagree nor agree
[4]Measured on a scale from 1 = not at all informed to 5 = extremely well informed

Table 4 cont'd. The measurement items used to assess psychological constructs in the Seneca County Demonstration Farm Tour survey

Psychological Construct	**Labels for Analysis (see Figure 4-6 in Results)**	**Measurement Items**
Cover crop implementation concern[1]		*How concerned are you about…*
	Terminate	The successful termination of winter cover crops.
	Cost	The short-term financial costs of cover crops.
	Establish	The successful establishment of winter cover crops.
	Aesthetic	Cover crops detracting from the way you want your farm to look.
	Uncertainty	The benefits of cover crops being uncertain.
	More Time	The management of cover crops being too time consuming.

[1] Measured on a scale from 0 = not at all informed to 4 = extremely well informed

3. Results

3.1. Mental Models Approach

3.1a Expert Model

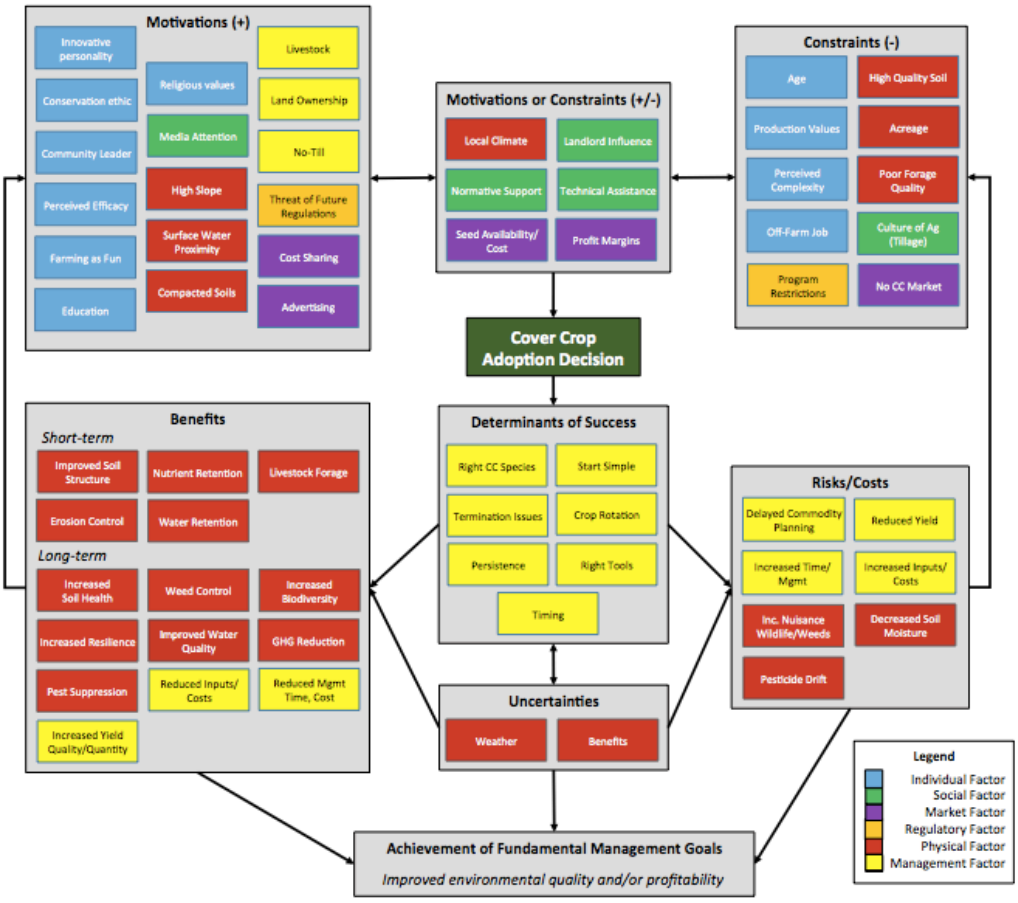
Collaborators on this research created the diagram below (see Figure 1) by coding the expert interviews and summarizing these codes in a conceptual influence diagram[1]. These concepts then formed the basis for our farmer interview guide and codebook. The expert model represents the main motivations and constraints identified by experts to be associated with the decision of whether to adopt cover crops. The model indicates that these motivations and constraints can be positive or negative, and include individual, social, market-based, regulatory, and other factors. Individual farmers may consciously consider the motivations and constraints when making the decision to adopt cover crops (e.g. the size of the farm and land tenure), while some of the factors may be more implicit in their influence (e.g. individual factors related to innovation and risk tolerance). The model also indicates that the decision to use cover crops has a set of associated risks and benefits. Even the benefits are not guaranteed, as they are a function of both inherent uncertainties in the agricultural system (e.g. the weather), and a set of management decisions that the individual farmer must make (i.e. determinants of success such as using the right tools, identifying the right cover crop species, etc.). Ultimately, whether the individual farmer achieves their fundamental management goals of improved profitability, or environmental quality, is dependent on the extent to which the balance is realized toward benefits versus risks or costs. If the decision results in significant costs, the farmer will then feel further constrained when making this decision in the future. While those who experience significant benefits across time will be further motivated to continue cover crop use. The way in

[1] The development of the expert model was completed outside the scope of this particular honors project and was completed by other members of the research team.

which these various factors in the decision making process influence one another are represented by the black arrows in the expert model (see Figure 1).

The model demonstrates that the decision to adopt cover crops is complex and includes interactions between numerous elements. By coding farmer responses according to the concepts represented in the expert model, it is possible to compare how closely a farmer's mental model matches with experts, and identify which factors considered important by experts are being highlighted the most among farmers.

Figure 1. Expert model of the cover crop adoption process[1]



[1]Wilson, R.S., Walpole, E., Carros, O.R., and Walpole, H. 2017. Meeting in the Middle: Engaging the Next Wave of Cover Crop Adopters. The Ohio State University, School of Environment and Natural Resources.

3.1b Farmer User Groups

We used the mental models data to categorize participants based upon their cover crop adoption status. Participants were also asked if cover crops were previously used or currently being used on their farms, answered simply as a "yes" or "no". However, responses regarding future cover crop use were more varied. To more accurately represent this variation, a scale has been created to better specify each participant's answers. This scale includes "yes", "no", and "maybe" as plausible answers from participants and is an important identifier of what group each participant is placed in (i.e. individuals who have used or are currently using cover crops but answer "maybe" or "no" when asked about future cover crop use would be considered tentative/non-adopters). Below is an example of a "yes" response to being asked about future cover crop use.

> "*Yeah I'm planning on using maybe triple the amount of acres I did this year, is what I'm thinking… Like I said, we're in the learning stages, but I am planning on putting more out again this year. I want to try it more and see what it's got. I don't want to just try it one time and not do it again. I want to keep doing it." –* (New adopter)

Below is an example of a "no" response to being asked about future cover crop use.

> *"I have no plans. I'm interested in them, but as of right now, so far, I haven't done anything about that."* – (Tentative/Non-adopter)

Below is an example of a "maybe" response to being asked about future cover crop use.

"I would say we probably will on a case by case basis." – (Tentative/Non-adopter)

Three user groups emerged based on their level of cover crop adoption and enthusiasm with cover crops:

1) Those that had been experimenting with cover crops many years and were very committed to continuing the practice, which we called the "enthusiastic" or "early" adopter group.
2) Those with less past experience and enthusiasm, but fairly sure they would continue planting cover crops; we called this the "new" or "middle" adopter group.
3) Those who were more skeptical of benefits and unsure if they would use cover crops in the future, if at all; we called this the "tentative" or "late" adopter group. (True non-adopters, those who had never and did not plan to use cover crops, only accounted for 2 individuals in our sample and were grouped with tentative adopters).

Respondents were assigned to one of the three groups based on how they responded to these sets of questions. For borderline cases, such as an individual with only 5 years of experience but high enthusiasm, final assignment to a category was made based on distinguishing qualities such as innovativeness and risk tolerance. For example, an individual with limited experience but high enthusiasm who was also coded as innovative and risk tolerant would be placed in the early or enthusiastic adopter group. From here on out we will refer to "early" adopters as "enthusiastic" adopters, "middle" adopters as "new" adopters, and "late" adopters as "tentative/non" adopters to remain clear and consistent. See Table 5 below for details regarding the current and future use of cover crops for the respondents in each user group.

Table 5. Cover crop usage in groups

Management Factors	Are currently using cover crops	Have used cover crops in the past	Will use cover crops in the future
Enthusiastic (7)	7 out of 7	7 out of 7	7 out of 7
New (6)	6 out of 6	6 out of 6	4 out of 6 yes, 2 maybe
Tentative/non (9)	5 out of 9	6 out of 9	3 yes, 4 maybe, 2 no

3.1c Cover Crop Perceived Efficacy and Benefits

We then analyzed the qualitative interview data focusing on the relative levels of perceived efficacy and benefits among the three groups. These results are presented here, and divided into three sub-sections: 1) Perceived efficacy, which represents the factors that contribute to whether a farmer thinks adopting cover crops would be a good idea for them and their farm (i.e., addresses issues of self-efficacy or confidence, and issues of response efficacy such as complexity in the system), 2) Perceived short-term benefits, which arise within the first year of adopting cover crops such as erosion control and providing forage, and 3) Perceived long-term benefits, which take time or repeated implementation of cover crops to be fully realized, such as increased soil health.

Perceived Efficacy

The code "perceived efficacy" refers to the belief that cover crops, despite their inherent complexity, can be used to successfully achieve goals on one's own farm. This sense of efficacy is affected by the availability of specific advice and support for his/her farm in particular, a

farmer's ability to engage in trial and error learning, and direct (or indirect) experience with successful establishment and termination. This code was most common among our new adopters and equally common between enthusiastic or tentative/non-adopters (67% vs. 43%, 44%). Comments from enthusiastic or new adopters were split between getting the idea to use cover crops from neighbor's successes, and gauging their own success by comparing their fields to their neighbors. In the case of tentative/non-adopters, there were 3 participants that were unique in providing examples of the challenges and failures they observed their neighbors having, to demonstrate the *inefficacy* of cover crops (these are not included in the reported sum). As an example of positive perceived efficacy:

> "*As far as others, seeing what they're doing influencing me, I got one neighbor that he's been doing it for almost as long as I have, and he just stays at it continually. He's a testament to how it does work because everybody watches it work and he just keeps right on going. So I know if he can do it, I can do it too.*" – (Tentative adopter)

The code "perceived complexity" was used when farmers describe the steep learning curve of cover crops, with a focus on possible complications, a lack of knowledge, or a lack of understanding of the benefits. Interestingly, these sentiments were most common among new adopters (67%), although they were also seen in roughly half of tentative/non-adopters (44%). There were no comments of this kind from enthusiastic adopters. The following is an example of perceived complexity:

> "*There's definitely a learning curve. A learning and a time curve that I didn't expect."* - (New adopter)

Perceived Short-Term Benefits

First, "erosion control" was the most salient benefit of using cover crops in our study, with the majority of enthusiastic (86%), new (67%), and tentative/non-adopter (78%) participants all mentioning it. While in the case of enthusiastic adopters, and in some cases new adopters, erosion control was one in a long list of benefits mentioned, erosion control was one of only a few benefits commonly mentioned by tentative or non-adopters. As a result, it can be concluded that erosion control was the most widely understood and visible benefit of using cover crops to our participants, at all levels of adoption.

Second, "livestock forage" was a less commonly cited benefit, with 2 individuals from the enthusiastic group mentioning it (29%), as well as one individual each from the new adopter and the tentative/non-adopter group. Interestingly, while two of the individuals mentioning forage benefits had livestock of their own, there were an additional 4 participants who currently or previously had livestock on their farms who did not mention the possibility of using or selling cover crops as forage.

Third, the benefit of "nutrient retention" was most well known to our new adopter group (50%), followed by tentative/non-adopters (44%), and lastly enthusiastic adopters (29%). Among enthusiastic and new adopters, these comments were most often related to reduced input costs or water quality issues. In the tentative/non-adopter group, and in some cases new adopters, these comments were most often related to anticipated yield increases, and occasionally reduced inputs, with a costs and profit-based focus. For example:

> "*...suppose if the cover crop didn't grow right and you didn't get a good stand. Which I have heard of that sometimes, and then you've got the investment of a seed, but if the government reimburses [that] you're really not out of much*

money. But, if the cover crop doesn't grow and doesn't give you a nutrient value, then you're right back to square one. So, you've invested fuel and labor into the process to save you some money, and it didn't happen." – (Non-adopter)

Fourth, the benefit of "water retention" was most on the minds of our new adopter group (50%) and enthusiastic adopters (43%), and rarely mentioned by tentative/non-adopters (11%). More specifically, water retention benefits included comments about reduced evaporation rates by keeping the ground shaded, as well as having improved water retention through higher soil organic matter or improved soil structure. This topic was often related to discussions of improved farm resilience, such as the ability for commodity crops to withstand hot or dry weather. For example:

"*We have some really variable soil with a lot of tight, clay hillsides and tops of hills and then we started with using the cereal rye cover crop. We had noticed that it definitely mellowed out the soil and made it much easier to plant and also it's more drought resistant now, in that it does absorb water better and it doesn't dry out as quick in the summer. We have seen some spotty areas in our field. We now have more consistent yields across the field."* – (Enthusiastic adopter).

"*We'd like it to soak in when we have too much water and we'd like it to hold the water when we have a dry spell ... So we're just trying to build resilience into the soil which, we don't have proof at this point, but we think cover crops help with that.*" – (New adopter)

Lastly, "improved soil structure" was another salient benefit of using cover crops to our participants. It was most on the minds of our new (83%) and enthusiastic adopter groups (71%),

as well as some tentative/non-adopters (44%). More specifically, the ability of cover crops to improve highly compacted soils seems to be an immediate and highly visible benefit of using cover crops to all levels of adopters, both in terms of improving water retention or drainage, and making planting or plant emergence easier. As an example:

> "*I think there's a benefit to the ground from what we've seen. It [the cover crop] did a great job with the roots... What it did to the soil – the structure of it – the spring was phenomenal. When the plane flew the rye on, there was some areas that didn't come up and some areas were five foot around in a circle. We took the shovel out there when the rye was probably two foot tall. There were worms in every single shovel that we dug up. You take the ground and crumble it and it just had a very nice structure to it for water infiltration."* – (Tentative adopter)

Table 6. Short-term benefits - Percent of individuals in each category that mentioned the specific short-term benefit of using cover crops

	Erosion control	*Livestock forage*	*Nutrient retention*	*Water retention*	*Improved soil structure*
Enthusiasts (7)	86%	29%	29%	43%	71%
New adopters (6)	67%	17%	50%	50%	83%
Tentative/non-adopters (9)	78%	11%	44%	11%	44%
Total (out of 22)	17	4	9	7	14

Perceived Long-term Benefits

First, "increased soil health", referring to increased soil organic matter or improvements to the biological soil system, was the most salient long-term benefit of using cover crops. (By comparison, it was also almost as salient as "erosion control"). While every enthusiastic adopter mentioned this benefit, 67% of new adopters and 56% of tentative/non-adopters also did so. These differences may be due to the long-term nature of this benefit (where enthusiastic adopters have more experience), but is likely related to conservation values. Discussion of this topic was often related to long-term farm improvement or sustainability goals, which were found in every enthusiastic adopter interview but less commonly expressed by tentative or non-adopters.

In addition, while several enthusiastic or new adopters mentioned soil health as a benefit that helped to offset seed costs, one tentative/non-adopter felt that soil health, while a worthwhile long-term benefit, did not help to pay the bills. As a result, it is possible that framing the already salient benefit of soil health in an economic sense (as opposed to a sustainability or conservation focus) may make it more appealing to tentative or newer adopters. The importance of improved soil health as a means of increasing water and fertilizer efficiency and overall farm resilience may be an important message moving forward as farmers have to deal with an increasingly variable climate.

Second, "increased biodiversity" was a less salient long-term benefit overall, with two enthusiastic adopters and one tentative adopter specifically mentioning cover crops serving to pollinators. One enthusiastic participant also mentioned the possible silver lining that the voles attracted to their cover crops were also attracting hawks and owls.

Third, the benefit of "weed control" from cover crops was quite salient to new and enthusiastic adopters, with 83% of new adopters and 43% of enthusiastic adopters describing

their first-hand experience, often in tandem with other benefits and cost-savings from reduced herbicide use. Tentative/non-adopters, however, did not mention this benefit at all, perhaps because most were engaged in conventional tillage practices, and thus weed control is less of a focus.

Fourth, the benefit of "pest suppression" was not salient to participants, with only one enthusiastic adopter mentioning it (specifically related to soil biodiversity and reducing cyst nematode populations). It was more often that participants mentioned pest and weed problems *resulting* from the adoption of cover crops. Also, the benefit of "greenhouse gas reduction" from using cover crops appeared in our expert model but not our interviews.

Fifth, the concept of "increased resilience" as a result of using cover crops was fairly popular among enthusiastic adopters, with 71% of them mentioning this concept. An additional one participant from the new adopter and tentative/non-adopter groups also contributed comments along these lines. More specifically, this was the idea that using cover crops made farms more resilient to the impacts of weather events such as flooding or dry periods due to erosion control, shading, and/or improved water retention:

> "*... So we're just trying to build resilience into the soil [by using cover crops] ... you can improve your chances of succeeding under really any circumstance: drought, any circumstance. If you have a good, healthy soil, I think it just helps you weather all sorts of problems. So I guess I like the idea of that [because there are so many things in farming you can't control*]." – (New adopter)

Often times these observations were made by comparing to the size or health of neighbor's crops during such events (that is, neighbors who did not use cover crops).

Additionally, there was the idea that cover crops "reduced inputs" (reducing the need for fertilizer, herbicide, or pesticide), which then made farms more resilient to market fluctuations:

> "*…my gut feeling is when this thing goes, it's gonna get to a point where it can be very hard to make a profit raising corn… And so my goal was I wanted to start raising crops with very, very little fertilizer. In other words, if I go out here and I can put in $20.00 worth of seed or $5.00 worth of cover crop seed and I can get the benefits of weed control, I can get some benefits for soil health, soil structure, increase my microbiology, [and] cut my fertilizer… I started [using cover crops] because of self-preservation, because I knew these markets were not going to hold where they were currently at*." – (Enthusiastic adopter)

The participants commonly mentioned "reduced inputs" although it was more common in the new adopter (50%) and enthusiastic adopters (43%) groups, than in tentative or non-adopter interviews (22%). Some enthusiastic (57%) and new (33%) adopters also shared their experiences of having reduced inputs on their farms as a result of adopting cover crops. No tentative adopters reported these experiences, potentially due to having fewer years of experience, on average. One enthusiastic participant shared that emphasizing these kinds of cost-saving benefits to farmers may help to increase adoption, and it was a more reliable outcome from our more experienced adopters than yield increases.

Related to the concept of resilience, some individuals felt that reducing inputs would give their farms more financial stability and control:

> "*The cost of these inputs, that's part of our control. We have control over those largely [compared to many other aspects of farming]. So, to the extent that we*

can reduce our dependence on those inputs, we have a better chance of just doing better financially over time." - (New adopter)

Seventh, the goal of "increased yield quality/quantity" was shared by six enthusiastic adopters, two new adopters, and one tentative adopter through descriptions of their own past outcomes. Among these nine individuals were a diversity of experiences related to cover crops and yields; one reported having more consistent yields as a result of using cover crops, three reported improved yields, another four said yields had roughly stayed the same, and one reported having yield drag for their first six years. Despite these mixed results, many of these individuals emphasized that even without yield increases the benefits of cover crops paid for themselves in other ways. Others felt that cover crops paid for themselves through longer-term yield bumps in addition to other long-term benefits:

"*Then as we tried it and did side-by-sides and looked at some longer-term things and stuff like that, then we started to see that for the most part, the yield benefits were paying the way. That made it real easy to accept it when it's not costing you anything. I mean, it's still work, another thing to manage and those kinds of things. Some years, the yield benefit more than covers the cost, and some years it's close or you come up a little bit short. When you can basically cover the cost and get all of these other benefits of building the soil and long-term improvement on the farm, then it really seems like a pretty logical thing to do.*" – (Enthusiastic adopter)

Although, considering how site and year-specific these yield results seem to be it may not be accurate for farmers to base their adoption decisions on the expectation of yield increases

alone. It may be better instead to focus on other long-term and cost-saving benefits, or methods of making income from cover crops (such as forage).

Lastly, the idea that "reduced management costs/time" can result from adopting cover crops, often in tandem with no-till, was raised by three enthusiastic adopters and two new adopters. As an example of this perspective:

> "*Trying to get stuff covered in the spring with some of this clay ground – they call it 24-hour clay. You've got 24 hours to open it up, get it fit back down, and plant. It's just hard. … Whereas with my cover crop stuff, I can go in – and it depends on the year and things a little bit, but a lot of times I can go in and put my burn down, throw my residual in with that in that first spray, and then all I've got to do is come back and plant. When the ground is ready, I can just come back and plant. I don't have that extra pass with the sprayer until we get into doing, whether it's foliar or maybe some escapes or some of that stuff that kind of stuff that we've got to do*." – (New adopter).

As another example:

> "*I mean, in some ways it saves us time because of just the benefits, I guess. I'm spending less time tilling. It's actually, it is nice, and I feel like in some ways I'm spending less time on working bare ground. Because, if you don't have cover crops, you're probably going to have some amount of weeds. And so, it's been a nice way to have ground covered and not be spending all your time dry fallowing and things like that. So, I think in some ways it is – it's like a hidden time-saving. Because, it seems like it's taking more time, but then if you actually think about*

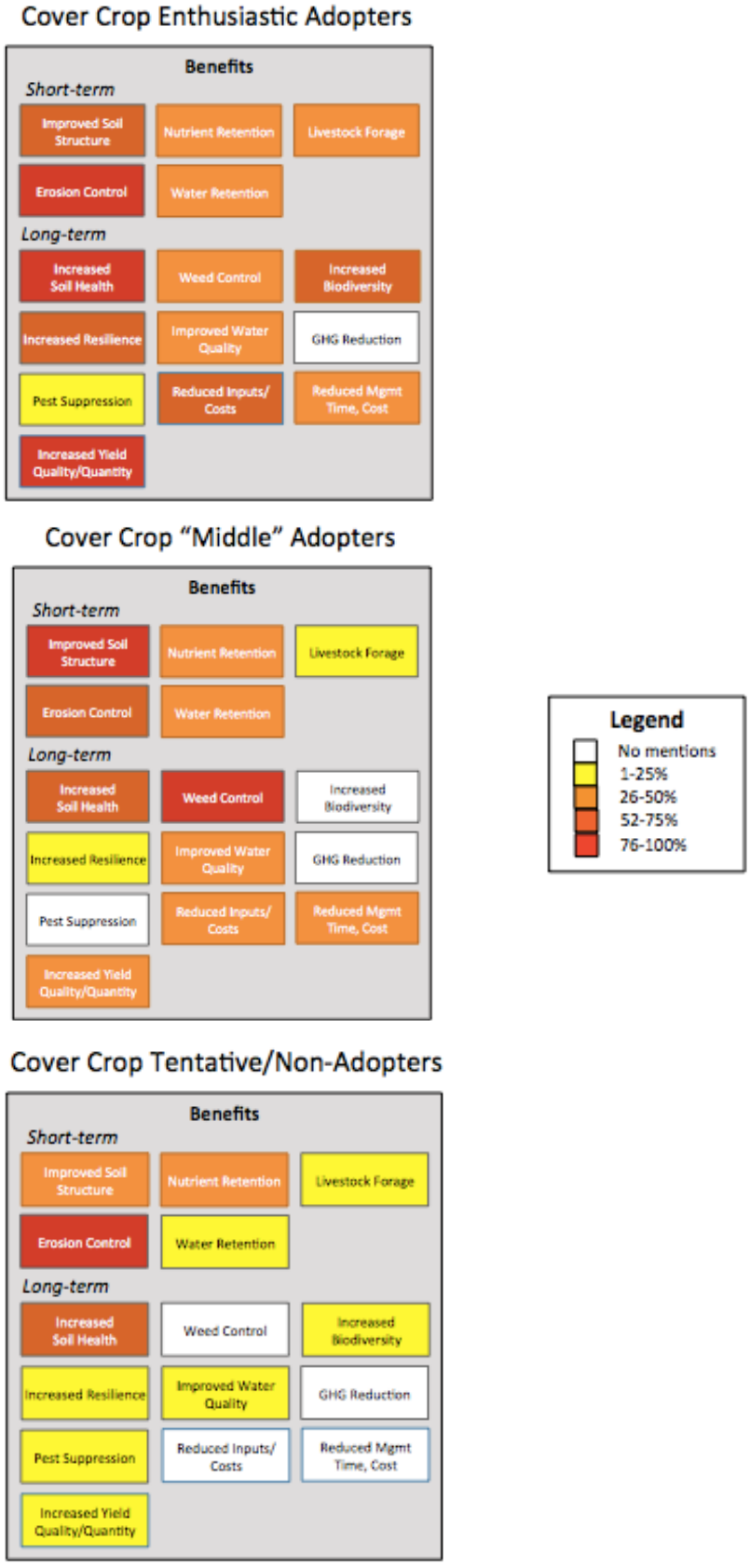
what you're spending time doing, you're spending less time on other things that you might be doing, like tractor work on bare ground." – (New adopter).

Table 7. Long-term benefits - Percent of individuals in each category that mentioned the specific long-term benefit of using cover crops

	Enthusiasts (7)	New adopters (6)	Tentative/non-adopters (9)	Total (out of 22)
Increased soil health	100%	67%	56%	16
Increased biodiversity	29%	0%	11%	3
Weed control	43%	83%	0%	8
Pest suppression	14%	0%	0%	1
Increased resilience	71%	17%	11%	7
Reduced inputs	43%	50%	22%	8
Increased yield quality/quantity	86%	33%	11%	9
Reduced mgmt. time /costs	43%	33%	0%	5

N = 0: "Greenhouse gas reduction"

Figure 2. Frequency with which benefits are mentioned by each group

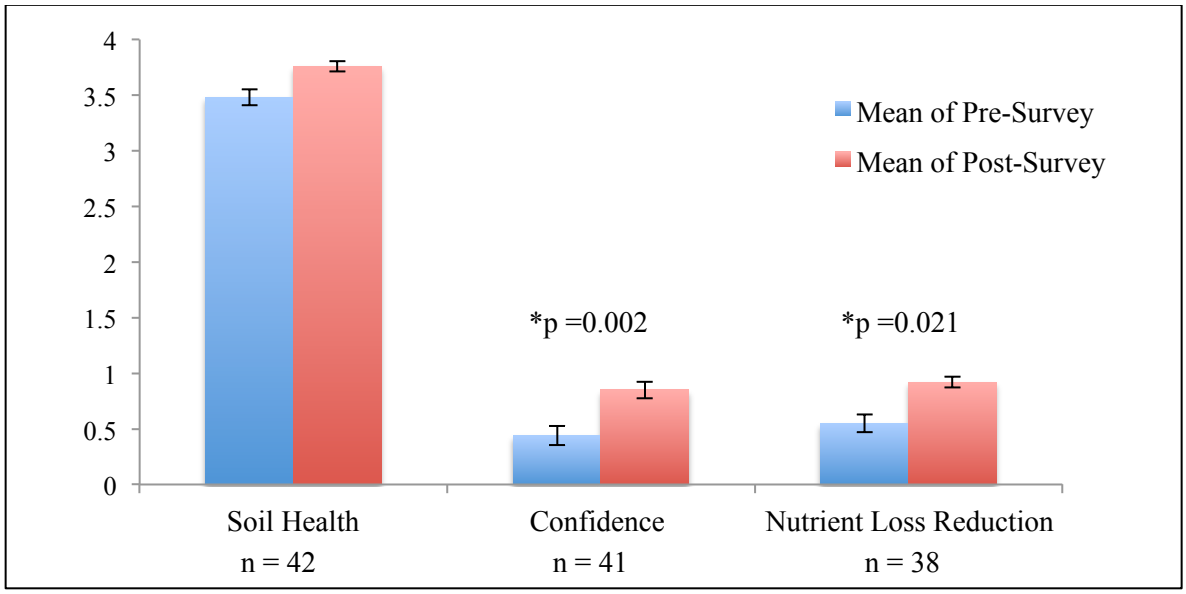


3.2. Demonstration Farm Surveys

3.2a Blanchard Valley Demonstration Farm Surveys

Participants responded to three questions rating their level of confidence and knowledge (see Figure 3). No significant increase was found regarding knowledge of soil health improvements through cover crop use ($p = 0.05$; "Soil Health" in Figure 3). However, we did find a significant increase in participants' confidence in their ability to use cover crops to improve soil health on a scale from -2 (strongly disagree) to 2 (strongly agree) ($\bar{\chi}_{\text{pre-test}} = .44$, $\bar{\chi}_{\text{post-test}} = .85$, $p = .002$; "Confidence" in Figure 3). We also found a significant increase in knowing what steps to take to reduce nutrient loss on the farm on a scale from -2 (strongly disagree) to 2 (strongly agree) ($\bar{\chi}_{\text{pre-test}} = .55$, $\bar{\chi}_{\text{post-test}} = .92$, $p = .021$; "Nutrient Loss Reduction" in Figure 3). The second hypothesis of this thesis is to determine whether demonstration farms increase perceived efficacy and knowledge of cover crops benefits to promote greater adoption. Based on these preliminary results, the hypothesis is partially supported.

Figure 3. Pre/post Blanchard Farm survey changes in efficacy and knowledge



3.2b Seneca County Demonstration Farm Surveys

The first three questions in this survey pertained to how informed participants felt about cover crops and soil health on a scale from 1 (not at all informed) to 5 (extremely well informed) (see Figure 5). We found no significant change in how informed participants felt about the benefits of cover crops on the farm (p = .387, "Benefits" in Fig. 5), improving soil health through the use of cover crops and no-till (p =.337, "Soil Health" in Fig. 5), or using cover crops effectively on the farm (p =.337, "Cover Crop Use" in Fig. 5).

The next six questions pertained to the participants' concerns about commonly cited challenges of implementing cover crops on a scale from 0 (not at all concerned) to 4 (extremely concerned). We found no significant change in concern about the successful termination of winter cover crops (p =.273, "Terminate" in Fig. 4), cover crops detracting from the way you want your farm to look (p =1.00, "Aesthetic" in Fig. 4), the benefits of cover crops being uncertain (p =.165, "Uncertainty" in Fig. 4), and the management of cover crops being too time consuming (p =.387, "Time" in Fig. 4). We did find a significant decrease in concern about the short-term financial costs of cover crops ($\bar{\chi}_{\text{pre-test}} = 1.46$, $\bar{\chi}_{\text{post-test}} = 1.00$, p =.027, "Cost" in Fig. 4) and the successful establishment of winter cover crops ($\bar{\chi}_{\text{pre-test}} = 1.23$, $\bar{\chi}_{\text{post-test}} = 0.85$; p =.018, "Establish" in Fig. 4).

The last four questions pertained to comfort and confidence (perceived efficacy) toward cover crop use on participants' farms on a scale from -2 (strongly disagree) to 2 (strongly agree). We found no significant change in participant level of confidence regarding risks associated with cover crops (p = 1.00, "Risks" in Fig. 6), soil health improvement through cover crop use (p = .583, "Soil Health" in Fig. 6), your ability to use cover crops on your own farm (p = .671, "Confidence" in Fig. 6), and knowing what steps to take to use cover crops on your own farm (p

= .671, “Steps to Use” in Fig. 6). The second hypothesis of this thesis is to determine whether demonstration farms increase perceived efficacy and knowledge of cover crops benefits to promote greater adoption. Based on these preliminary results, the hypothesis is not supported; however, farmer concern regarding short-term financial costs and challenges surrounding successful establishment of winter cover crops decreased. Additionally, since there were so few participants, it is difficult to determine significance without a larger sample size.

Figure 4. Pre/post Seneca County survey changes in concern (n = 13)

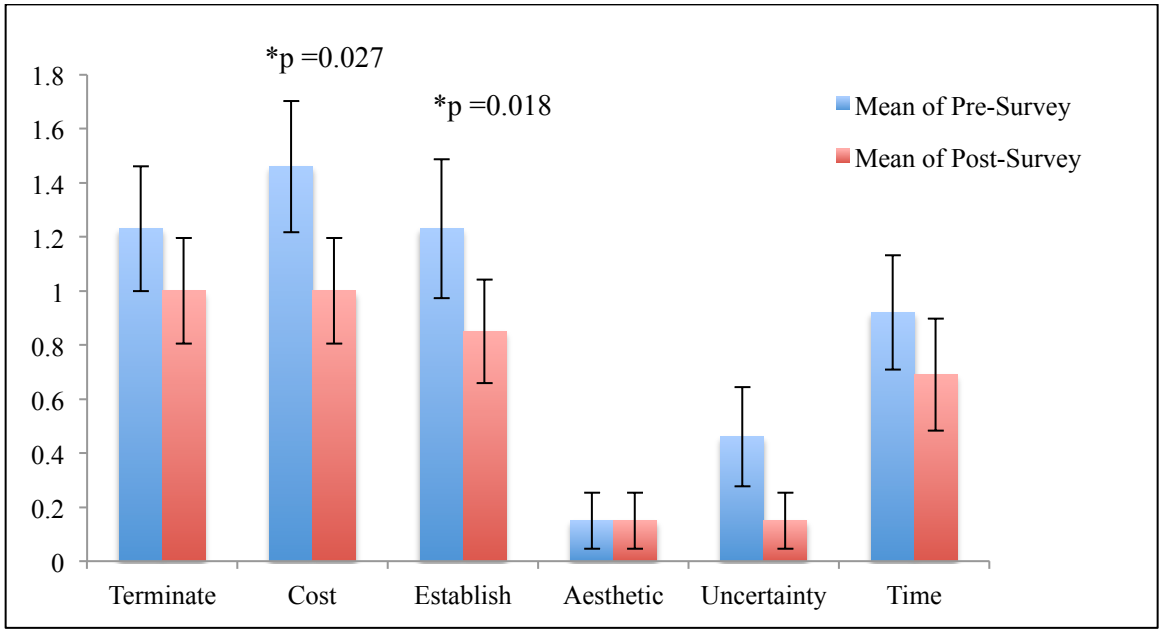


Figure 5. Pre/post Seneca County survey changes in knowledge (n = 13)

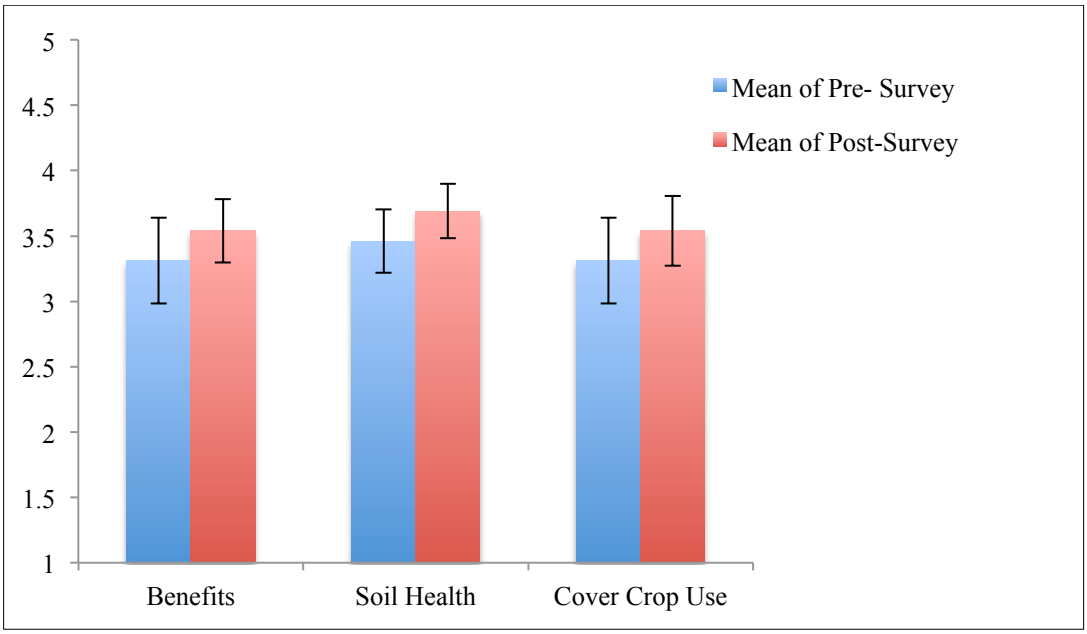
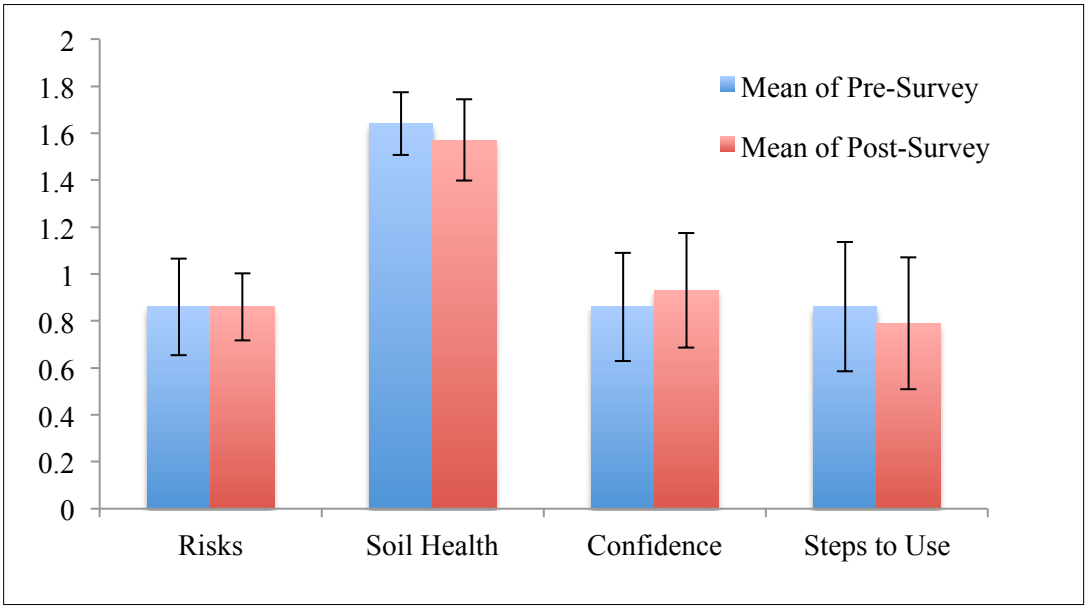


Figure 6. Pre/post Seneca County survey changes in efficacy (n = 14)



4. Discussion and Summary of Findings

The first hypothesis of this thesis is that greater perceived efficacy and knowledge of the diverse benefits of cover crops will increase the likelihood that an individual has already adopted cover crops. Three clear cover crop user groups emerged based on experience with and enthusiasm regarding cover crops: "enthusiastic" adopters, "new" adopters, and "tentative"/non-adopters. This first hypothesis was partially supported because enthusiastic adopters were found to have the greatest knowledge of benefits, perhaps due to their long-term experiences with cover crops. However, new adopters had the greatest perceived efficacy (67% of new adopters mentioned this code; ~40% of the rest of the groups). The efficacy results are consistent with Burnett et al. (2018) findings, where authors suggest that how effective the farmer believes cover crops are in reducing runoff is not just a result of adopting cover crops and seeing their results firsthand, but is also a belief that precedes and motivates adoption. White and Selfa (2012) found that factors that appear most likely to influence farmer decisions to adopt a new practice include the ability to learn about and discuss it through existing social networks. Since new adopters have enthusiastic adopters to look toward for concrete examples of success, new adopters can see the advantages of cover crops firsthand without having had to experiment on their own farms as extensively through trial and error. They may also have more available outreach events to attend than enthusiastic adopters had when enthusiastic adopters began to adopt, further increasing their efficacy.

The second hypothesis was that demonstration farms would increase knowledge of cover crops benefits, promoting greater efficacy and ultimately greater adoption. This hypothesis was partially supported by Blanchard survey results and not supported by Seneca County survey results. Blanchard Valley survey results show that farmer confidence in their ability to use cover

crops to improve soil health increased, as did knowing what steps to take to reduce nutrient loss. Knowledge regarding soil health benefits did not increase. Seneca County results show knowledge and efficacy did not increase, but there was a statistically significant decrease in farmer concern regarding short-term financial costs of cover crops and the challenges surrounding successful establishment. Decreases in concerns about cover crop challenges are important for increasing farmer comfort and confidence over time, so this is a positive result given the goals of the demonstration farm event. Additionally, the sample size for this survey was much smaller than anticipated, so although the trends were often in the expected direction, the small sample may have limited the power of our analysis. Interestingly, the Seneca County results showed that farmer confidence in knowing what steps they need to take to use cover crops on their farm actually decreased. Unexpected reactions could have emerged as survey participants were exposed to information on the tour and asked questions in the survey that, intentionally or otherwise, increased perceptions of personal risk (Byrne & Niederdeppe 2012). Individuals on the Seneca County tour may have learned about cover crop implementation challenges that they did not know about before, possibly becoming more concerned because cover crops could have started seeming more complex and risky. A concern about these events is that they may increase knowledge, but not efficacy to the degree needed because these events may be less personalized and tailored to farmer interests and concerns. Additional data must be collected to determine more conclusively whether demonstration farms increase farmer knowledge and efficacy, and how to improve such events moving forward.

Digging into the qualitative results a bit more, erosion control was the most salient and widely understood short-term benefit of using cover crops across all groups, perhaps due to prior outreach and its high visibility. However, it should be noted that erosion is more of a problem on

hilly farms and often regarded as a problem on other people's farms by farmers, making it a poor messaging strategy overall. If an individual farmer does not perceive their fields to have erosion issues, than they may not perceive cover crops as necessary under current messaging strategies. Improved soil structure was another visible and salient benefit, although it was more commonly mentioned by enthusiastic or new adopters than tentative or non-adopters. Similarly, improved water retention was a benefit more commonly mentioned by enthusiastic or new adopters than tentative or non-adopters. Improved soil structure and water retention should be emphasized to farmers that are considering cover crops instead of erosion control, particularly in a manner that appeals to production-oriented values (i.e. managing risk and costs). Nutrient retention may also have potential for more emphasis as a means of offsetting costs (less fertilizer needed) or improving yields.

In addition, using cover crops as livestock forage was rarely mentioned by participants, despite the fact that 36% of our participants had or previously had livestock on their farms, and several more mentioned the high prevalence of animal operations in their area. Considering the interest that our tentative and non-adopter participants had in offsetting the costs of cover crops, the possibility of using cover crops as forage on one's own farm, or the possibility of entering into partnerships with neighbors who have animals, could also be emphasized.

Interestingly, tentative/non-adopters did not mention "reduced management costs/time" as a benefit of adopting cover crops. In fact this perspective was quite counter to this group's numerous and serious concerns about the *increased* time and costs associated with using cover crops. While many of the constraints mentioned during the interviews were legitimate, increased management time may be a misperception. Specifically, there are hidden time savings from the additional nitrogen made available to cash crops from cover crops, which reduces fertilizer and

nutrient application requirements (Marcillo & Miguez 2017). These potential time savings could be made more explicit for tentative/non-adopters, highlighting that the time savings may be even more noticeable for those who incorporate cover crops into a no-till system. It is crucial to correct these assumptions or help newer adopters use cover crops in a more time-efficient way, perhaps by combining them with no-till practices.

Distinctions between enthusiastic and newer adopters were more extreme for long-term benefits than short-term, with tentative and non-adopters having low awareness of most long-term cover crop benefits with the exception of increased soil health. While partially understandable given their more recent experience with cover crops (they may not have observed these benefits first-hand) this result points to a potentially important communication opportunity. Emphasizing the long-term benefits of adopting cover crops may help to overcome some short-term costs and risks, especially if they are framed in a production-oriented way (Wilson et al. 2017). In particular, the benefits of increased soil health, weed control (in both no-till and tillage systems), and improved resilience may help to reduce inputs or reduce farm risks overall, but take time to achieve. Based on the Blanchard Valley Demonstration Farm Tour results, demonstration farms can be a useful tool for increasing farmer confidence in their ability to use cover crops to improve soil health. Newer and tentative adopters should be prepared for these outcomes with a longer-term mindset. However, increased biodiversity, greenhouse gas reduction, and pest suppression seem to be less salient benefits to any level of adopters, and likely should not be the main emphasis of communication.

Interestingly, new adopters were also the most likely to describe the perceived complexity of adopting cover crops. This is possibly because they are still in a trial-and-error phase of implementation on their farms, with more hands-on experience of this complexity than

the tentative/non-adopters. The failure to mention complexity by enthusiastic adopters is either emblematic of more innovative and risk-tolerant personalities, or simply the result of experience and having found a system that works well for their farm (Wilson et al. 2017). However, the presence of this sentiment among newer adopters may present a communication opportunity, and the need to promote more simple cover crop species and plans (at least to begin). As farmers toured the Seneca County Demonstration Farms, their concerns decreased regarding short-term financial costs of cover crops and the challenges surrounding successful establishment of winter cover crops. These results are useful because new and tentative/non-adopters may be more willing to adopt or expand cover crops if they see cover crops working on surrounding farms with farmers they perceive as similar to them having cover crop success.

Individuals in the new adopter group seem to be the most motivated by other cover crop adopters. Of our three groups, new adopters are the most aware of their neighbors' experiences and most likely to draw comparisons to their own and other's experiences with cover crops. This result is somewhat expected, given the independence expressed by many of our enthusiastic adopters, and the separatist style of commodity farming expressed by some of our tentative/non-adopters. Tentative/non-adopters rarely described instances of negative or positive peer pressure, which was a factor that could motivate or inhibit the adoption of cover crops. Less engagement with neighbor farmers and "keeping to themselves" was commonly mentioned and could lead to less positive or negative pressure to adopt cover crops. New adopters were most likely to be motivated to use cover crops by seeing the results other farmers were getting, as well as to seek the most advice and encouragement regarding cover crops from "in-group" friends or local communities. According to Van der Ploeg (1994), a farming style can be thought of as a composite of normative and strategic ideas about how farming should be done that develops over

time into a particular unity of thinking and doing – a "cultural repertoire". These cultural repertoires then guide behavior. As cover cropping becomes more common in areas, non-adopters may become motivated to adopt cover crops to ensure a culturally relevant farming style consistent with those individuals in the farmer's area. While a larger sample will be needed to confirm if this trend holds true in the broader population, a potential lesson from this is that mixing between groups, in this case enthusiastic adopters with new adopters could be beneficial and educational. Blanchard Valley Demonstration Farm Tour results show that farmer confidence increased in knowing what steps to take to reduce nutrient loss. Promoting demonstration farms, which may be organized or led more commonly by enthusiastic adopters, could allow for mixing between groups and increased peer-to-peer learning.

In sum, erosion control was the most salient and widely understood benefit of using cover crops across all groups, followed by improved soil health, improved yields, and improved soil structure. However, we found that tentative and non-adopters are unaware of or not thinking about many of the benefits that can be provided by cover crops, particularly those that take several years to materialize. This suggests that improved communication and cost-benefit analyses could be used to advertise the diverse and economically beneficial outcomes of using cover crops such as water retention, nutrient retention, weed control, improved resilience, and livestock forage. Water and nutrient retention in particular may become more critical in the future as farmers may be pressured to continue improving nutrient and water efficiency (Wilson et al. 2017). These messages should include quantified payoffs (such as the case of reduced inputs and reduced risk to weather and market fluctuations) to appeal to production values as much as possible and help to emphasize payoffs over time (such as the break even point given the short-term investment or the time it takes to achieve the return on investment).

In addition, it was found that tentative adopters and non-adopters, as well as some new adopters, were quite focused on the yield-improving benefits of using cover crops, often as a requirement for continuing to use them. Considering the mixed results that our more experienced cover crop adopters had with yields (where they either saw short-term decreases, increases, yearly fluctuations, or no changes), communication may be required to emphasize other positive impacts that cover crops can have on a farm's bottom line. Framing cover crop adoption as having long-term cost-savings and diverse benefits may help to reduce reliance on yield increases and possible frustration when such increases do not materialize, as well as help to overcome aversion to the annual costs of adoption. In particular, numerous cover crop benefits can be framed as methods of reducing production risks in the long-term, which will likely appeal to many tentative/non-adopters with a yield-based focus.

5. Communication Recommendations

Within the field of communication there are several possible approaches to improving the reception and adoption of a new behavior. First, the type of information contained in a message and how it is presented (or "framed") can be altered to make it more appealing to an audience based on their goals or motivations (Wilson et al. 2017). For example, talking about the on-farm benefits of cover crops as opposed to the water quality benefits. In addition, how this message is distributed and by whom (for example, federal employees versus family; in-person or online) has also been found to have a large impact on how a message is received (Burnett et al. 2018). A summary of our recommendations are organized by these areas below:

Content-based (informational) recommendations:

1) Conduct and provide better cost-benefit analyses to clearly quantify benefits for farmers (i.e. in dollars and cents), recognizing that cover crop performance may vary over time and that realizing the economic benefits requires a long-term commitment.
2) Do not focus on erosion control benefits. Instead, focus on benefits that improve resilience (e.g. by reducing nutrient loss, improving season-long weed management regardless of current tillage practices, improved water retention).
3) Suggest leveraging livestock opportunities as a means of receiving benefits (such as their possible use as forage, and a way to received free or cheap fertilizer in the form of manure from local operations)
4) Since farmers on demonstration farm tours had no significant decrease in concern regarding the management of cover crops being too time consuming, time savings created by cover crops should be made explicit by providing examples from local, successful adopters.
5) Improve the perceived self-efficacy or confidence of farmers in their ability to implement cover crops by providing simple steps and guidelines to maximize success.
6) Use the following key message for new adopters: start simple with one, easy-to-manage cover crop on perhaps limited acreage to get experience.

Message delivery strategies (source; framing; etc.):

7) Develop farmer success profiles across a range of farm and farmer types (not just demonstration days, but videos and other narrative approaches) of larger farms implementing simple cover crop strategies, to show relevant-feeling "recipes" for other new adopter farmers. Avoid from promoting complex mixes and new technologies.

8) Use peer-to-peer opportunities for learning and mentorship, such as demonstration farm tours. Preliminary results show these tours can be successful but need additional research with larger samples before more concrete conclusions can be drawn. Understanding more about how different events are conducted may shed light on what is relatively successful versus what is not as useful at increased perceived efficacy and benefits.
9) Farmers can be an excellent source of one-on-one training (Jennings et al. 2012). Demonstration farm tours should focus less on extension agent presentations and more on farmer-to-farmer learning as this is one of the most common ways for information dissemination. A network of enthusiastic adopters should be developed to serve as demonstration farm leaders for farmers in their county or state to learn about conservation practices through observation (Jennings et al. 2012).

Overall, early adopters can influence new and tentative/non-adopters by sharing their success and modeling the desired behavior (e.g., cover crop use). Using innovative and enthusiastic adopters as case studies of success will help shift the norm toward the standard that cover crops are what "we" do in agriculture. New adopters are still highly motivated, but may benefit from decision tools that help simplify the management process. Tentative/non-adopters should be the focus of future outreach and communication. They need more tailored "recipe books" to help them address management challenges, and they need examples of successful farmers and demonstration farm tours that are inexpensive or free and local to increase their comfort and confidence with cover crops. More research should be conducted regarding demonstration farm success as there is limited data available suggesting how these events are conducted, what aspects are successful, and if they are truly impacting cover crop adoption rates

and BMP adoption rates overall. Tentative/non-adopters would greatly benefit from more concrete examples of the long-term economic benefits to the farm, which could be promoted through well-designed demonstration farm tours and farmer success stories. If farmers perceive long-term benefits as psychologically distant, meaning the benefits might occur far in the future to other farmers in other places, they may be less likely to adopt cover crops. Demonstration farm tours can reduce psychological distance by promoting benefits in concrete ways that emphasize how people similar to oneself achieve benefits now, in the local community. Local farmer success stories may also be particularly useful because research suggests that individuals find narratives more engaging than traditional logical-scientific communication (Dahlstrom 2014). Because many new adopters have yet to experience many long-term benefits, new adopters will be dependent on enthusiastic adopters to inform and help them interpret information about benefits.

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Appendix A: Codebook

Section	Code	Description
Motivations/Constraints		
Individual		
	Innovative personality (+)	Risk tolerant, curious, open-minded, not married to the status quo, interested in problem solving. Willing to experiment and seek out information on cover crops themselves (the information is out there, but you need to be motivated to go get it yourself)
	Conservation ethic (+)	Holds conservation/environmental values, interested in stewardship/legacy, takes the long term view and responsibility for collective problem. Wants to make farm better or at least maintain quality and/or acting on a historical legacy of conservation practices on the farm/in the family
	Community leader (+)	A desire to set an example for others; strives to support other farmers in CC adoption
	Religious Values (+)	Religiosity drives responsibility/stewardship
	Age (-)	Older generation is not motivated to learn/change; too close to retirement
	Perceived efficacy (+)	A belief that CCs works in different contexts and can work on one's farm; results from exposure to peer success stories and site specific evidence; belief in site-specific success.
	Production values (-)	Holds profit/production values, doesn't see economic benefit of CC - takes a short-term view focusing on profit over conservation practices
	Perceived complexity (-)	Feels there is a steep learning curve: focus on complication (mixes), lack of knowledge, and/or lack of understanding of benefits
	Farming as fun (+)	Perceptions of farming being fun impacting cover crop usage
	Off farm job (-)	Full time or part time career can lead to time management issues and no time for cover crops

	Education (+)	Impact of education level on cover crop usage
Social		
	Landlord influence (+/-)	A need to make a landlord happy can be a motivation or a constraint based on landlord desires
	Technical Assistance (+/-)	Having access to trusted expert information/experienced one-on-one coaching. Help to develop a cover crop regime that works well with your farm; tailored information
	Media attention (+)	Blame placed on farmers for water quality issues
	Normative Support (+/-)	Negative/positive peer pressure, desire for social acceptance/fear of being identified as different, driven by the community/farming collective. Has a broad social network that supports cover crops
	Culture of ag. (-)	Culture of tillage (farm should look like your garden), masculinity/attachment to big equipment (CC and low/no till uses less big equipment). Sticking to traditional agricultural practices historically used on the farm/in the family that doesn't involve conservation practices
Market		
	Profit Margins (+/-)	High commodity prices (wider error margin for innovators), versus low commodity prices/high rent and equipment costs (CC easy expense to cut out)
	Advertising (+)	Positive advertising about CC in ag. publications, seed dealer/applicator promotions
	Cost-sharing (+)	Participation in incentive-based programs to off-set costs of CCs
	Seed availability (+)	Availability of desired seed at a price you're willing/able to pay
	No CC market (-)	Lack of market for CC decreases the potential for concrete short-term benefits
Regulation		
	Threat of Future Regulation (+/-	Adoption as a means to avoid future water quality regulation, desire to act before regulation forces adoption; CC as a BMP

)

Program Restrictions (-)	Assistance programs are too one-size fits all; e.g., CC use may make you ineligible for crop insurance, or there are too many program restrictions. Or, township or other local regulations are too strict or out of touch.

Management Factors

Livestock (+)	Having livestock increases the benefit of CC as forage, as a way to treat manure, or a way to financially support farmers while they experiment with cover crops
Land ownership (+)	Owning the land increases responsibility and a focus on long-term benefits, CC could hinder your competitiveness for rental land if unpopular
No-till (+)	CC works best in combination with no-till, benefits occur faster in systems with a longer history of no-till

Physical Characteristics

High slope	Sloped region get more erosion benefits
Surface Water Proximity	Proximity to a river reduces effectiveness due to flooding
Compacted Soils	Highly compacted soils take longer to respond
Local Climate	I.e. wet regions see less water retention benefit, arid regions see less water quality benefits, individuals in northern climates have shorter seasons, less flexibility in timing
High Quality Soil	High quality soils reduce the need for CC as a means to improve soil health/function
Acreage	Having too much acreage makes CC too costly; cannot leverage economies of scale
Poor Forage Quality	Decreases benefits of forage for livestock if the quality is poor, livestock won't eat it/could get sick

Determinants of Success

	Persistence	It can take several years of use to see concrete benefits. Also, experimentation and needing to tailor a system to your own farm is somewhat required; "trial and error" over several years.
	Right CC species	It is necessary to choose the right CC species for your resource goal, (cereal rye is to the most basic option)
	Timing	It is necessary to time planting and termination appropriately to accomplish your resource goal
	Termination Issues	Describes problems associated with terminating cover crops
	Right tools	Need to use the right planting tools for your species/latitude/topography (broadcast/drilling/intercropping/aerial seeding)
	Crop Rotation	Crop rotation impacts CC effectiveness (diverse rotations are better, having grains in rotations makes timing of CCs potentially better
	Start simple (New)	Being cautious; starting cover crops in a small plot and/or with one type to try it out. A new concept raised in interviews but not by experts.

Uncertainties

	Benefits	Lack of clarity about when benefits will occur and/or have a positive effect on yield bottom line
	Weather	The weather (temperature, moisture) can complicate planting/termination and decrease potential benefits

Benefits

Short term	*Erosion control*	Reduce soil erosion
	Livestock forage	Provide forage for livestock
	Nutrient retention	Retain nutrients (nitrogen fixing, phosphorus retention)

	Water retention	Reduce evaporative rate (efficient water use), Improve moisture/hydrology (increased retention), and/or increasing evapotranspiration
	Improved soil structure	Improve soil structure/drainage (like flooding reduction, reduced compaction
Long term	*Increased soil health*	Increase soil organic matter/health/biological system
	Increased biodiversity	Attract desirable wildlife/pollinators
	Weed control	Control weeds
	Pest suppression	Suppress pests
	GHG reduction	Serve as a carbon sink to reduce greenhouse gases
	Increased resilience	Increase resilience to extreme weather, and/or established CC users are insulated from market fluctuations due to diversified products or reduced inputs
	Reduced Mgmt. time / costs	Management is cheaper or easier because of using cover crops. A new concept raised in interviews but not by experts
	Increase yield quality/quantity	Protect/increase yield quality or quantity
	Reduced inputs	Reduce need for fertilizer, herbicide, or pesticide use
Risks/Costs	*Increased costs*	Increased farm costs (seed, equipment/labor, chemicals, fuel, or wear on equipment), More organic matter can require more N to stabilize C (short-term expense)
	Decreased soil moisture	Reduced soil moisture
	Delayed commodity	Problems terminating (perception that CC may behave as a weed)

planting	
Increased time	More management/time, Reduced speed of harvest
Increased nuisance wildlife/ weeds	Increase in undesirable wildlife/pests, insects or weeds
Reduced yield	Yields may go down as a result of adopting cover crops; competition for nutrients, crowding; termination problems or lingering herbicide damage. A new concept raised in interviews but not by experts.
Pesticide drift	Spray from neighboring fields can affect/kill cover crops

Fundamental Goals

Improve water quality	Improve water quality; help with algal blooms